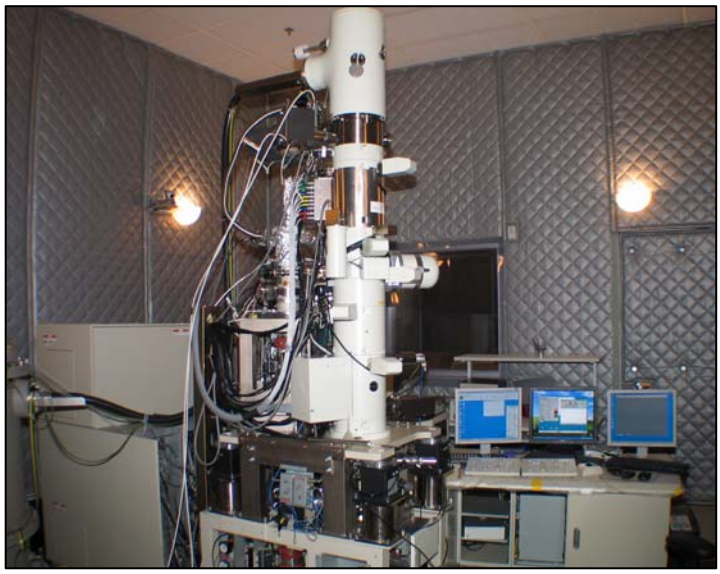
Ultra-High Resolution Electron Microscopy for Catalyst Characterization

Background

In order to provide information to better understand the structures of catalyst materials for reduction of emissions of oxides of nitrogen (NOx) in automotive and diesel exhaust systems, the Oak Ridge National Laboratory (ORNL) has acquired a new aberration-corrected electron microscope (ACEM) capable of imaging and chemical analysis of these materials at the single atom level. The first of a new generation of aberration-corrected microscopes capable of both conventional transmission and scanning transmission imaging has recently been installed in the newly built Advanced Microscopy Laboratory at ORNL. The ACEM, built by JEOL Ltd. (Akishima, Japan), will yield a resolution in the sub-Ångstrom range (an Ångstrom, Å, is 10^{-7} mm, or about the diameter of an average atom), so that single atoms of, for example, platinum on the surface of a catalyst support such as alumina can be imaged. The sub-Å resolution is achieved in the dark-field, or so-called "Z-contrast" mode of operation (Z = atomic number), so that higher atomic number species show up as bright contrast against the darker background of lower atomic number species. The new microscope is thus the ideal instrument to characterize the initial structure of catalysts in the "as-prepared" condition (when the



JEOL 2200FS-AC aberration-corrected STEM/TEM, during installation at ORNL in 2004

Benefits

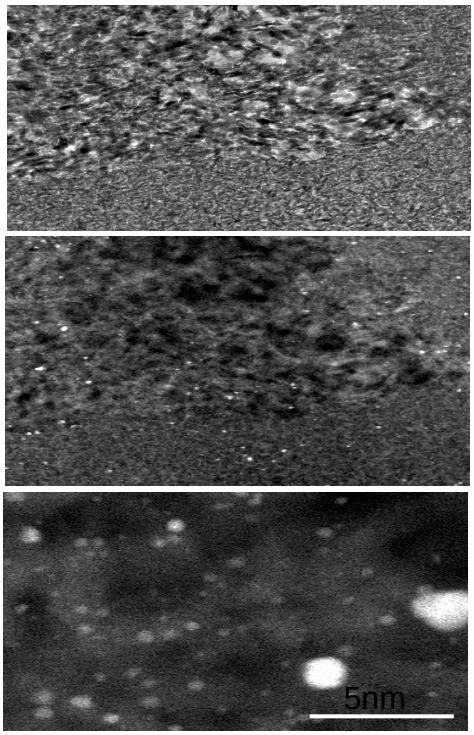
- The most advanced catalyst imaging capability available to DOE programs is available to industry, academia, and other federal agencies through the HTML User Program
- Will further the understanding of the important mechanisms for catalyst deactivation with use
- Knowledge of microstructural changes on aging will facilitate development of durable catalysts for NOx abatement
- Will attract the top catalyst researchers in the country as DOE collaborators

catalytic species are typically distributed as clusters at the near-atomic level), and after exposure to typical operating conditions (either in bench-top reactors or in actual vehicle tests) to determine the effects of catalyst aging on the structure and chemistry of the material.

The Technology

Initial tests of the ACEM showed the ability to achieve a resolution of 0.7Å in Z-contrast mode, and 0.9Å in conventional imaging mode, making this the first instrument in the world to demonstrate this capability.

The new microscope has been utilized to obtain information on the structure of a lean NOx trap catalyst from a Toyota vehicle. The figures to the right show the benefits of the Z-contrast mode of imaging for showing the size and distribution of the catalytic species in the as-prepared catalysts. The top figure is a conventional bright-field image, in which the platinum (Pt) particles cannot be unambiguously identified. The middle image is the corresponding dark-field image that clearly shows the Pt particles in bright contrast. The lower image at ultra-high resolution shows Pt species at or near the single atom level. This capability will be further utilized in advanced studies of catalysts of interest in the Department of Energy's FreedomCAR and Vehicle Technologies Program.



FreedomCAR & Fuel Partnership

21ST CENTURY TRUCK PARTNERSHIP

Where Can I Find More Information?

DOE Technology Manager
Sid Diamond
Department of Energy
202-586-8032
Sid.Diamond@ee.doe.gov

ORNL Project Manager
Larry Allard
Oak Ridge National Laboratory
865-574-4981
allardlfjr@ornl.gov

Printed on recycled paper

March 2005